Version with Markings to Show Changes Made

1. (Amended) A method for reducing the amount of computations required to create a sound signal representing one or more sounds originating at a plurality of discrete positions in space, where the signal is to be perceived as simulating one or more sounds at one or more selected positions in space with respect to a listener, comprising the steps of:

(a) determining a special characteristic function for a position in space at which sound originating at a plurality of positions in space is to be received, wherein said characteristic function represents a head-related impulse response;

(b) applying said characteristic function as a filter to the signal representing sound to produce a filtered signal; and

(c) converting the filtered signal to a sound wave and producing the sound wave for a listener;

wherein a special characteristic function is determined for a selected number of samples and a selected number of eigen values.

8. (Amended) A method of reducing the amount of computations required to create a sound signal representing one or more sounds originating at a plurality of discrete positions in space, where the signal is to be perceived as simulating one or more sounds at one or more selected positions in space with respect to a listener, comprising the steps of:

(a) determining a spatial characteristic function for a position in space at which sound originating at a plurality of positions in space is to be received, wherein said characteristic function represents a head-related impulse response;

(b) applying said characteristic function as a filter to the signal representing sound to produce a filtered signal; and

(c) converting the filtered signal to a sound wave and producing the sound wave for a listener;

wherein the spatial characteristic function is determined for a selected number of N samples and a selected number of M eigen values and wherein the model filter function for an azimuth position θ and an elevation position φ of sound originating in a spherical coordinate system about the position of sound measurement as the origin has the form

$$y(n) \quad = \quad \sum_{m=1}^{M}\left[\sum_{k=1}^{K} w_m(\theta_k,\varphi_k)s_k(n)\right]q_m(n)[.] \quad 9(c)$$

where s represents a sound source, K represents the number of independent sound sources, $w_m(\theta,\varphi)$ are the weighting factors, and $q_m(n)$ is a vector representing an orthonormal basis for a head-related impluse function.

9. (Amended) Apparatus for providing sound created by a sound source to a listener which simulates the sound source at a selected position in space with respect to the listener, comprising:

(a) an input for receiving a signal representing sound originating at a plurality of positions in space, said plurality of positions including multiple reflections, multiple sources without reflections, and multiple sources with multiple reflections;

(b) a left channel and a right channel, wherein each channel comprises a filter array for applying a filter to the signal received by the input to provide a filtered signal, the filter comprising a linear function including a spatial component which comprises a head-related impulse response;

(c) an output for converting the filtered signals from said channels to a binaural sound and for producing the sound for a listener.

21. (Amended) An apparatus for efficiently simultaneously processing a simulation of a plurality of sound signals in a three dimensional space, each channel within said apparatus comprising:

at least one delayer for delaying a sound source signal;

at least one attenuator for attenuating a sound source signal;

a plurality of filters for filtering said attenuated sound signal;

a plurality of weighting elements to weight said filtered sound signals; and

a summer for summing said filtered sound signals;

wherein said plurality of filters remain constant, with at least one of said at least one delay element, said at least one attenuator, and said plurality of weighting elements adapted to change a perceptive position of said sound source signal to a listener; and

wherein said plurality of sound signals comprise multiple reflections, multiple sources without reflections, and multiple sources with multiple reflections.

23. (Amended) A method for efficiently simultaneously processing a simulation of a plurality of sound signals in a three dimensional space, each channel within said apparatus comprising:

delaying a sound source signal;

attenuating a sound source signal;

filtering said attenuated sound signal;

weighting said filtered sound signals; and

summing said filtered sound signals;

wherein said filtered attenuated sound signal remains constant, with at least one of said delayed sound source signal, said attenuated sound source signal, and said weighted filtered sound signals are adapted to change a perceptive position of said sound source signal to a listener; and

wherein said plurality of sound signals comprise multiple reflections, multiple sources without reflections, and multiple sources with multiple reflections.

25. (Amended) An apparatus for efficiently simultaneously processing a simulation of a plurality of sound signals in a three dimensional space, each channel within said apparatus comprising:

means for delaying a sound source signal;

means for attenuating a sound source signal;

means for filtering said attenuated sound signal;

means for weighting said filtered sound signals; and

means for summing said filtered sound signals;

wherein said means for filtering said attenuated sound signal remains constant, with at least one of said means for delaying said sound source signal, said means for attenuating said sound source signal, and said means for weighting said filtered sound signals are adaptived to change a perceptive position of said sound source signal to a listener; and

wherein said plurality of sound signals include multiple reflections, multiple sources without reflections, and multiple sources with multiple reflections.

REMARKS

Claims 1-77 remain pending in the application, claims 27-77 being withdrawn by the Examiner.

Allowable Claims

The Applicant thanks the Examiner for the indication that claims 8, 16-20, 22, 24 and 26 are either allowed or recite allowable subject matter. The subject matter of claims 22, 24 and 26 are amended into their respective independent claims 21, 23 and 25.

Claim 8 objection

Claim 8 was objected to under 35 USC section 112, second paragraph, for a noted informality. Claim 8 is amended herein to correct the noted informality. It is therefore respectfully requested that the objection now be withdrawn.

Claims 1-7, 9, 13, 14, 21, 23 and 25 over Begault and Chen

In the Office Action, claims 1, 2, 9, 13, 21, 23 and 25 were rejected under 35 USC 102(b) as allegedly being anticipated by U.S. Pat. No. 5,438,623 to Begault ("Begault"); and claims 3-7 and 14 were rejected under 35 USC 103(a) as allegedly being obvious over Begault in view of U.S. Pat. No. 5,500,900 to Chen ("Chen"). The Applicant respectfully traverses the rejection.

With respect to claims 21, 23 and 25, the subject matter of **allowable** claims 22, 24 and 26 are amended respectively into claims 21, 23 and 25. It is respectfully believed that the Examiner would agree that claims 21, 23 and 25 are now also allowable for the same reasons that she indicated that claims 22, 24 and 26 were allowable.

Similarly, claims 9-15 are amended herein to include the **allowable** subject matter of claims 22, 24 and 26. Thus, again, it is respectfully believed that the Examiner would agree that claims 9-15 are patentable for all the reasons that claims 22, 24 and 26 are patentable.

With respect to the remaining claims 1-7, claims 1-7 are amended herein to recite a characteristic function representing a head-related **impulse response** includes a special characteristic function determined for a selected number of samples and a selected number of **eigen values**.

Neither the cited art of Begault nor Chen disclose, teach or suggest eigen values at all, much less a head-related **impulse response** **including** a special characteristic function determined for a selected number of **eigen values** as now claimed by claims 1-7.

Begault teaches a head-related **transfer function** that can be recorded using an impulse response. (Begault, col. 1, lines 54-57). Begault discusses the digital implementation of the binaural impulse response by convolving the input signal in the time domain with the impulse response of two HRTFs using two finite impulse response filters. (Begault, col. 1, lines 59-63). However, Begault fails to teach the use of **eigen values** as specifically claimed by claims 1-7.

Chen teaches a free-field-to-eardrum transfer function (FETF, an previous name for an HRTF) developed by comparing auditory data for points in three-dimensional space for a model ear and auditory data collected for the same listening location with a microphone (Abstract). Each FETF is represented as a weighted sum of frequency-dependent functions obtained from an expansion of a measured FEFT covariance matrix (Chen, Abstract). Spatial transformation characteristic functions (STCF) are applied to transform the weighted frequency-dependent factors to functions of spatial variables for azimuth and elevation (Chen, Abstract). A generalized spline model is fit to each STCF to filter out noise and permit interpolation of the STCF between measured points (Chen, Abstract). A spline model used to generate the STCFs, smooths measurement noise and enables interpolation of the STCFs between measurement directions (Chen, col. 5, lines 18-20). A regularizing parameter within the spline model controls a trade-off between smoothness of a solution and its fidelity to the data (Chen, col. 5, lines 29-31).

Neither Begault alone, nor Begault combined with Chen, disclose, teach or suggest filtering based on a head-related impulse response including a

characteristic function determined for a selected number of samples and a selected number of **eigen values**, as claimed by claims 1-7.

There are significant advantages of using eigen values as claimed by the present invention. For instance, as disclosed in the specification of the present application in the last paragraph of page 4, "[i]nstead of representing HRIR using measured discrete samples at many directions, the present invention employs a linear combination of a set of eigen filters (EFs) and a set of spatial characteristic functions (SCFs)." These eigen filters are functions of frequency or discrete time samples only (i.e., NOT dependent upon distance). Thus, the need for the creation of a separate HRTF for each source and each early reflection as is conventionally required is avoided. (See, e.g., specification, page 3, lines 5-7).

Accordingly, for at least all the above reasons, claims 1-7, 9, 13, 14, 21, 23 and 25 are patentable over the prior art of record. It is therefore respectfully requested that the rejections be withdrawn.

Conclusion

All objections and rejections having been addressed, it is respectfully submitted that the subject application is in condition for allowance and a Notice to that effect is earnestly solicited.

Respectfully submitted,

William H. Bollman
Reg. No. 36,457

Manelli Denison & Selter PLLC
2000 M Street, NW
Suite 700
Washington, DC 20036-3307
TEL. (202) 261-1020
FAX. (202) 887-0336